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FERMILAB-PUB-77-134-E

SCALING OF MULTIPLICITY DISTRIBUTIONS FROM p-EMULSION COLLISIONS AT ENERGIES BETWEEN 6.2 GeV AND 300 GeV.

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The multiplicity distributions from p-nucleus interactions in emulsion are found to be consistent with the KNO semi-inclusive scaling hypothesis for p-p collisions, without any change in parameters. The applicability of the scaling law has been extended from current FNAL energies down to 6.2 GeV. The results indicate a fundamental consistency in the multiplicity distributions, regardless of the size of the target nucleus.

Slattery[1] has shown that the Koba-Nielsen-Olesen semi-inclusive scaling hypothesis[2] is in agreement with the data from p-p interactions in the momentum range 50-300 GeV/c. Since then attempts have been made to test the validity of the scaling hypothesis for the case of p-nucleus collisions in emulsion. Martin et al.[3] found that in order to apply the scaling hypothesis to multiplicity distributions from p-emulsion collisions, the parameters in the Slattery scaling function [$\Psi(z) = (Az + Bz^3 + Cz^5 + Dz^7) \exp(Ez)$ where $z = n_{ch}/\langle n_{ch}\rangle$] have to be modified. With new values for the parameters A, B, C, D, and E, the authors observe that the scaling hypothesis agrees reasonably well with the experimental data at 30, 67 and 300 GeV. Hébert et al[4] argued that since emulsion is a composite target, one should first examine whether the multiplicity distribution from each constituent group of nuclei obeys the scaling hypothesis. The authors pointed out that it is not valid to reduce the multiplicity distribution for p-emulsion collisions to a form such as that obtainable for p-p collisions and that the only way to test the scaling hypothesis is to derive the multiplicity distribution for each group of nuclei from the p-p scaling function and then combine the various distributions to produce an expected multiplicity distribution. Using the Slattery scaling function with no change in the parameters (except that $\psi(z)$ is divided by 2 in order to account for the observed odd prong events), the authors showed that the scaling hypothesis holds for p-emulsion interactions at 200 and 300 GeV.

In this letter, we attempt to verify the validity of KNO scaling for p-nucleus interactions below 30 GeV. We make use of the scaling function used by Buras et al[5], who extended the range of applicability of the semi-inclusive scaling hypothesis in the case of p-p interactions. This scaling function has the form, $\psi(z) = A(z + B) \exp(Cz + Dz^2)$ where $z = (n_{ch} - \alpha)/$

$<n_{ch} - \alpha>$, the value of α being close to unity. Buras et al suggested that for a multiplicity distribution to obey the scaling relation, $\psi(z) = (<n> - \alpha)\sigma_n/\sigma_{in}$, the modified moments $C_N = <(n - \alpha)^N>/(<n> - \alpha)^N$ should be nearly independent of energy and the N^{th} roots of the central moments $(\mu_N)^{1/N} = (<(n - <n>)>)^{1/N}$ when plotted as functions of $<n>$ should yield a set of straight lines intercepting the $<n>$ axis at α.

Examining the p-emulsion data[4,6-8] we find that the central moments of the multiplicity distributions plotted against $<n_s>$ yield a family of straight lines which intercept the $<n_s>$ axis at approximately zero (Fig. 1). This implies that for p-emulsion data $\alpha \simeq 0$ and the absolute moments $C_N = <n_s^N>/<n_s>^N$ should be independent of energy. The value of C_N for N = 2, 3 and 4 are given in Table I.

TABLE I. Some absolute moments of the multiplicity distribution.

Energy (GeV)	C_2	C_3	C_4
6.2	1.33 ± 0.07	2.10	3.78
14[7]	1.39 ± 0.15	2.35	4.58
22.5	1.35 ± 0.10	2.19	4.04
67	1.38 ± 0.13	2.39	4.93
200	1.35 ± 0.09	2.28	4.54
300	1.35 ± 0.07	2.25	4.35

The constancy of C_N indicates that if we put $z = n_s/<n_s>$ in the scaling functions of Buras et al., it should be possible to derive the multiplicity distribution for p-emulsion interactions. The results of such calculations for data from Refs. 6-8, 4 are shown in Figures 2 and 3 respectively. The χ^2 values for the fits are given in Table II.

TABLE II χ^2 test for scaling fits

Energy (GeV)	χ^2	Degrees of freedom
6.2	14.0	8
14[7]	39.1	14
22.5	24.2	17
67	38.9	31
200	64.6	42
300	74.9	52

At every energy considered, events with $n_s = 0$ were excluded in the computation of χ^2 since the efficiency of detection of such events is low. At 14 GeV, there is a large fluctuation in the observed frequency for $n_s = 10$, 11 (resulting in a large value of χ^2) which may be due to the wide spread in the beam energy.

The fact that $\alpha \simeq 0$ for the p-emulsion data indicates that the target particles are not included in the shower particles in the majority of cases. This conclusion is supported by the observation of Calucci et al.[9] that in a p-p collision there are 0.48 slow protons and 0.12 slow pions. Whereas in the bubble chamber experiments these slow particles are included in the value of $\langle n_{ch} \rangle$, in emulsion experiments they are counted as heavy tracks. In fact, when the loss of these slow particles is taken into account, it turns out that the contribution to $\langle n_s \rangle$ from the target nucleons is only $\simeq 0.2$. The implication of this observation in comparing p-p and p-emulsion data will be discussed in a forthcoming publication.

Finally, it should be noted that the above considerations imply that the values of $\langle n_{ch} - 1 \rangle / D$ for p-p interactions (where the dispersion D is equal to $(\mu_2)^{\frac{1}{2}}$, and $<n_s>/D$ for a pure nuclear target (as opposed to a composite target such as emulsion) should be practically the same. Thus, there appears to be an underlying consistency in p-nucleus interactions at high energies regardless of the size of the target nucleus.

The contributions to the data used at 200 and 300 GeV by the participants in our collaboration (Belgrade, Lund, Nancy, Paris, Rome and Valence) are gratefully acknowledged. We wish to thank also the FNAL staff for assisting in the exposure of the emulsion stacks at 200 GeV and 300 GeV.

This work was made possible through awards from the National Research Council of Canada and the Institute of Particle Physics.

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FIGURE CAPTIONS

Fig. 1 Plots of $(\mu_N)^{1/N}$ (where μ_N is the N^{th} central moment) for N = 2, 3 and 4 as functions of $\langle n_s \rangle$ for p-emulsion collisions from 6.2 GeV up to 300 GeV.

Fig. 2 Shower particle distributions from p-emulsion experiments. The experimental points are from Refs. 6-8 and the curves are calculated from the scaling function.

Fig. 3 Shower particle distributions from p-emulsion experiments. The experimental points are from Ref. 4 and the curves are calculated from the scaling function.

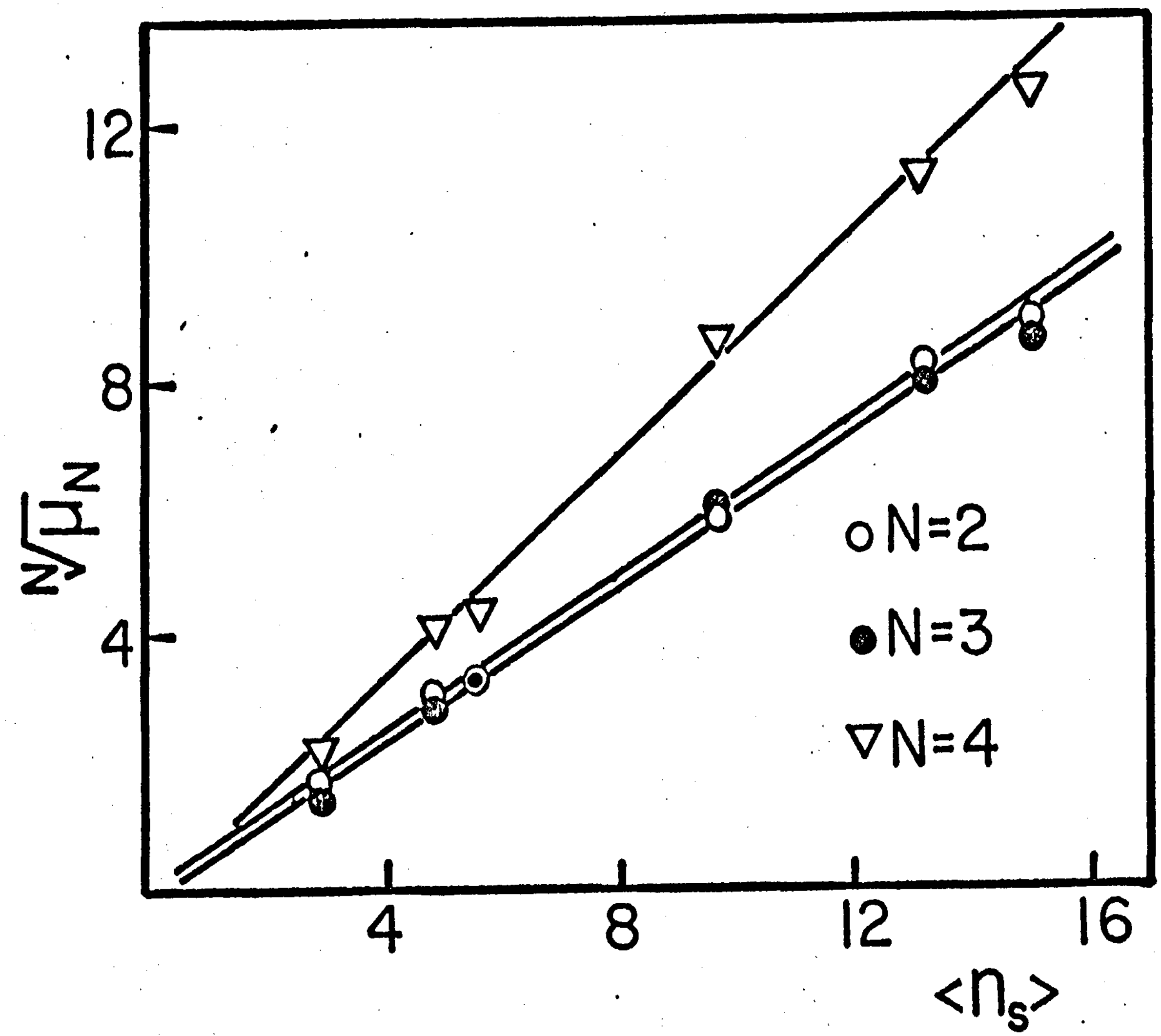
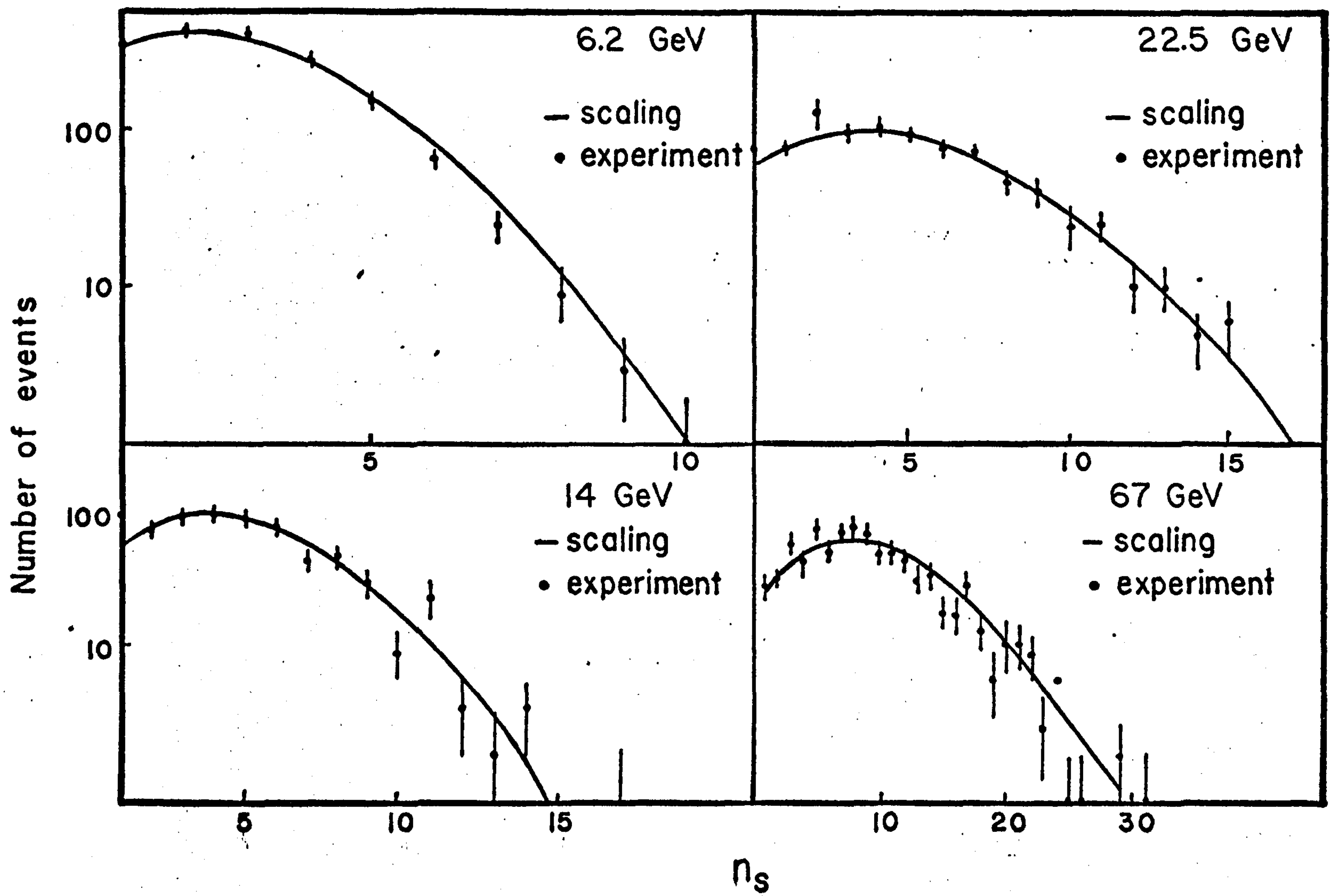


Fig. 1



6.2 GeV
— scaling
• experiment
22.5 GeV
— scaling
• experiment
14 GeV
— scaling
• experiment
67 GeV
— scaling
• experiment
Number of events
100
10
5
10
15
20
30
n_s

Fig. 2

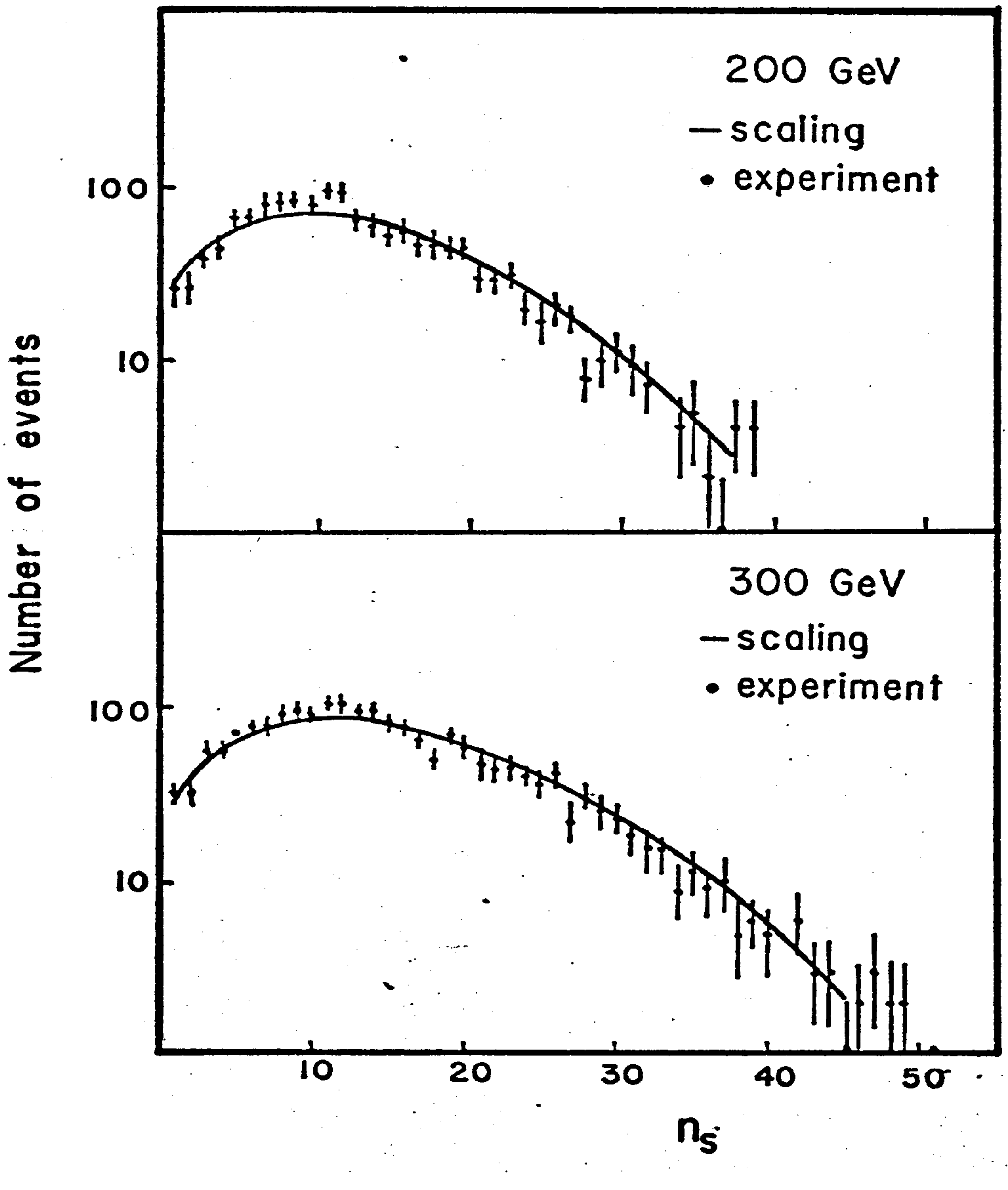

200 GeV
— scaling
• experiment
300 GeV
— scaling
• experiment
Number of events
100
10
100
10
10
20
30
40
50
n_s

Fig. 3